

MATERIALS SCIENCE AND PROCESSING STRATEGIES FOR INTEGRATION OF PIEZOELECTRIC AND ULTRANANOCRYSTALLINE DIAMOND (UNCD) THIN FILMS FOR PIEZOACTUATED HYBRID MEMS

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Abstract

The integration of dissimilar materials and micro and nanofabrication processes need to be investigated and developed to enable a new generation of multifunctional microelectromechanical and nanoelectromechanical system (MEMS/NEMS) devices. Ultrananocrystalline diamond (UNCD) with exceptional mechanical strength, chemical inertness and tribological performance exhibits great potential as a new high-performance material for application to MEMS and NEMS. On a parallel scientific and technological path, ferroelectric/piezoelectric $\text{Pb}(\text{Zr}_x\text{Ti}_{1-x})\text{O}_3$ (PZT) thin films has attracted much attention due to projected applications for intelligent MEMS based on its outstanding piezoelectric and electromechanical coupling coefficients, easy dipole reorientation and high remnant polarization. However, PZT exhibits relatively weak mechanical and tribological properties that hinder its application into MEMS/NEMS devices as a strong microstructural material. Therefore, the opportunity exists for integrating these two dissimilar materials for fabrication of piezoelectrically actuated MEMS/NEMS devices. PZT films need to be grown in O_2 at high temperatures (600-700 °C) on the UNCD layers to achieve the proposed integration. However, growth of PZT, at high temperature in oxygen, on UNCD layers, results in chemical etching of the diamond surface due to formation of volatile CO and or CO_2 species. Another critical challenge lies in the thermal stress between PZT and UNCD that might cause film delamination, following deposition and annealing processes. We demonstrate here that a bi-functional TiAl alloy film can be used as an oxidation barrier and adhesion layer interposed between the PZT and UNCD layers in combination of using conductive metallic or oxide electrode to achieve a successful integration of these two dissimilar materials. Low-temperature thin film growth techniques, including magnetron sputter-deposition for producing the TiAl barrier layer, and MOCVD to produce $\text{PbZr}_x\text{Ti}_x\text{O}$ (PZT) layers, were used to lower the risk of diamond oxidation. Post-deposition rapid thermal annealing was used to control the crystallography orientation of the PZT layer, thus its piezoelectric properties. The UNCD films were grown by CVD using an Ar-rich CH_4/Ar plasma chemistry. First PZT-films based capacitors with excellent polarization hysteresis loops were produced on UNCD structural layers using the integration described above (see Fig. 1). This result demonstrates the viability of using piezoelectric PZT layers for actuation of UNCD-based MEMS devices. Processing for producing piezoactuated PZT/UNCD cantilevers will be discussed in view of projected applications to the fabrication of piezoelectrically actuated UNCD-based MEMS/NEMS actuators and sensors.

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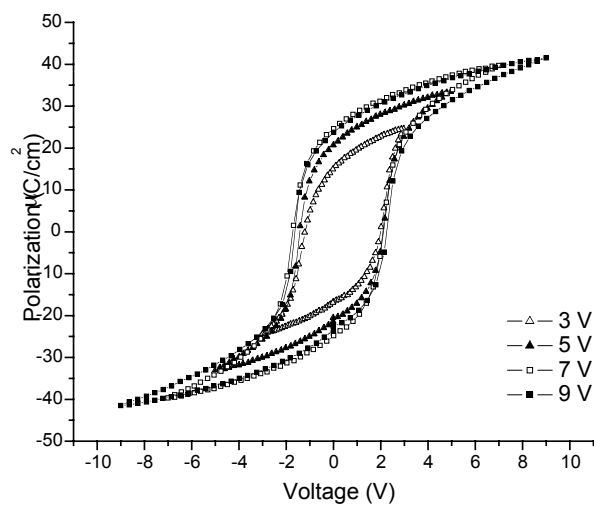
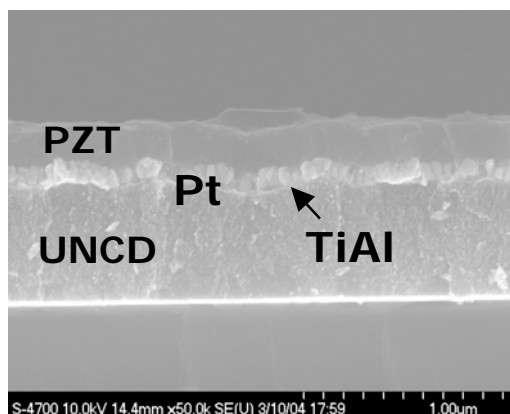


Figure 1. (a) Cross section SEM picture of integrated PZT/UNCD films with TiAl diffusion barrier layer; (b) first polarization hysteresis loop demonstrated for PZT capacitors fabricated on a diamond (UNCD) layer.